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THE USE OF THE MEMBRANA TYMPANI AS A PHONAUTOGRAPH AND LOGOGRAPH.

By CLARENCE J. BLAKE, M.D., Boston.

(With a heliotype plate: Otol. Tab. III.)

The various forms of instruments constructed for the purpose of obtaining tracings of sound-waves, and to which the name of phonautograph has been given, differ but little in their mechanism, and consists principally of a resonator, or mouth-piece, open at each end, the smaller opening being closed by a membrane to which is attached a pen or style by means of which the vibrations of the membrane are traced upon smoked glass or prepared paper, moving at right angles to the direction of excursion of the style, the movement being affected either by drawing the plate horizontally or by fastening the prepared paper to a revolving drum.

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The first instrument constructed by Scott* consisted of a hollow ellipsoid. The sound-producing body was placed in one focus of the ellipsoid, while the membrane was stretched at the other focus. König improved this instrument by giving it the form of a paraboloid and constructed it of metal; various improvements were also made in the manner of setting the membrane, which in the later instrument is so arranged that, by means of set screws, the metallic ring which holds it may be placed at different angles of inclination to the long axis of the mouthpiece, and its tension increased or diminished at will. The manner of attachment of the style has also undergone several variations, the latest improvement being that of Mr. Morey, of the Massachusetts Institute of Technology, who attaches a style made of light wood to the periphery of the membrane by means of a strip of gold-beater's skin; contact with the membrane being effected by means of a short rod, also of light wood, attached to the style and resting upon the centre of the membrane. The

* Report of the British Association, 1859. Pisko, *Die neueren Apparate der Akustik*, 1865.

2 style or arm projects a distance of a foot or more beyond the periphery of the membrane, and has at its end a strip of metal which makes a tracing upon a plate of smoked glass drawn horizontally at right angles to the direction of excursion of the style.

The membranes employed in these instruments have been either thin bladders, gold-beater's skin, thin rubber cloth, or even parchment paper and collodion film; the gold-beater's skin has generally best answered the purpose, is easily prepared and readily obtained.

The experiments made by Bourget and Bernard,* Marx,† and especially by Donders‡ and by later observers, show that, under the same circumstances, that is, with the same tension of the membrane and the same length and weight of the style, each sound produces its distinctive curve. Various tone colors possess various curves, and each individual tone has its corresponding compound curve. Each vowel sound has a

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corresponding curve, the curves produced by *u*, *ue* and *i* being very nearly the same. The form of the curve, however, changes with the pitch of the vowel.

* Sur les vibrations des membranes carrées.

† Studien ueber die Schwingungen der Membranen. Bindseil's Akustik.

‡ Zur Klangfarbe der Vocale. Pogg. Ann. 1864. Pisko. Neueren Apparate der Akustik.

In sounding the diphthongs, the duration and form of the transition from one vowel to the other is distinguishable in the tracing. Consonants sounded before the vowel change the form of only the first part of the tracing; sounded after the vowel, of only the last part of the tracing. § The experiments made with the membrana tympani used as a phonautographic membrane, substantially confirm the above observations as stated by Donders, with this advantage, that the far greater delicacy of the means employed in experiment have made it possible to detect minute variations in the forms of the curves; in the tracings thus obtained, for instance, the difference between the corresponding curves of *u*, *ue* and *i* are made more marked. The differences consequent on changes in pitch and on varying degrees of tension show more plainly in the almost microscopic tracings obtained from the

§ Donders, loc. cit.

3 membrana tympani than in the tracings made by the coarser mechanical device of the mechanician.

The desire to obtain a more delicate instrument led to a series of tests with various membranes, and finally to the use of the human membrana tympani, and to the experiments the results of which are to be given in further communications.

It is readily comprehended that a structure so admirably fitted by nature for the office which it has to fulfill—the reception and transmission of sonorous vibration—should better answer the purposes of experimentation than any merely mechanical device. The

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accompanying structures, also the malleus and incus with their attachments, may be made available in the adaptation of the organ to its mechanical uses. The proportionate distribution of the weight of these bones, as shown in a previous paper,* is such as to constitute a counterbalance, as it were, to the larger proportion of weight lying above the axial line of vibration of the malleus and incus, thus favoring the vibration of the membrana tympani under certain conditions of tension, and enabling it to transmit more readily the delicate impulses of the shorter soundwaves corresponding to the higher musical tones.

* Mechanical Value of the Distribution of Weight in the Ossicula. C. J. Blake. Trans. Am. Otological Society, 1874.

The membranes employed in these experiments have been preferably those of the human subject, as being most readily obtainable under favorable conditions, as presenting the greatest delicacy of structure and of adaptability to the purpose, and as affording opportunity also for the study of the method of transmission of sonorous vibrations in addition to the purpose of merely obtaining tracings similar to those obtained from the mechanical membrane phonautograph.

In preparing the membrana tympani for use, a specimen as nearly normal as possible is obtained, the temporal bone removed and cleaned, the auricle and other soft parts removed, and the lining of the external auditory canal cut away to a line close to the membrana tympani.

The tegumentum tympani is then cut away by means of a bone chisel, great care being taken to avoid disturbing the ossicula. The opening should be sufficiently large to permit a clear view of the cavity from the antrum mastoideum posteriorly to the opening of the Eustachian tube anteriorly, uncovering the malleus and incus, and extending inward so far as to reveal the inner tympanic wall and the articulation of the incus and stapes.

This latter articulation is then divided by means of a narrow-bladed knife or paracentesis needle, and the musculus tensor tympani also cut across close to the insertion of its

tendon on the malleus; or, if it be desirable to retain this muscle for experiment, in which it may be used for traction to increase the tension of the membrana tympani, its belly is dissected out from the bony canal in which it is lodged. A section is then made from behind forward through the tympani cavity, separating the petrous from the mastoid and squamous portions of the temporal bone, a hair-saw being used for this purpose and carried between the incus and stapes through the divided articulation.

At this point the saw should be inclined inward toward the stapes, and the descending process of the incus pressed gently outward by means of a spatula, in order to avoid any movement of the incus, a touch of the saw upon the bony process of the incus being often sufficient to rupture the capsular ligament of the articulation of the malleus and incus, and so far derange the relations of the ossicula as to render the specimen unfit for experiment. The petrous portion of the temporal bone with the stapes having been removed by this section, the inner surface of the membrana tympani is freely exposed with the malleus and incus in position. The outer portion of the floor of the tympanum is then removed with a file or the Rüdinger knife, and the specimen cleaned of the small pieces of bone and the bone dust which would otherwise load the membrana tympani and interfere with its vibration or obstruct the movement of the ossicula. As the specimen becomes dry it is moistened with a mixture of equal parts of glycerine and water. To obtain tracings of the soundwaves conveyed to the membrana tympani, it is necessary that the specimen be firmly fixed, that a style should be attached to the membrane, and that a plate, upon which the movements of the style are to be traced, should be carried smoothly and at a uniform speed in a direction at a right angle to the direction of the excursion of the style. For this purpose the specimen is attached, by means of thumb-screws passing through holes bored 5 in the squamous portion of the bone, or by means of a clamp, to a perpendicular bar sliding in an upright and moved by a ratchet-wheel. (See Otol. Tab. III.) To the upright is affixed horizontally a metallic stage having a glass bed six inches in length, upon which slides a glass carriage carrying a glass plate. The carriage is drawn by a weight on the end of a cord passing over a wheel at the end of the stage and attached to the carriage.

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A flexible bell-shaped mouth-piece, or a conversation tube, is inserted in the external auditory meatus and luted in position. A musical tone sounded in the bell or mouth-piece being conveyed to the membrana tympani, will set it in corresponding vibration.

These vibrations may be observed by means of a light ray thrown upon small specula made of foil attached to the malleus, incus, or different parts of the membrana tympani, or may be recorded by a style tracing upon the smoked glass plate resting upon the carriage.

The character of the style is a matter of considerable importance; it should be very light and firm, and sufficiently elastic to bend easily when its point is pressed upon the glass plate, and should be so stiff as to have but little vibration of its own. After a series of unsuccessful, or but partially successful attempts made with styles of horse-hair, bristles, cane fibres, split bamboo and the like, the best style for the purpose was obtained by splitting long wheat straw, scraping the inner cortical substance away, and separating single fibres; these could be obtained of any desired length, and so far have answered all that has been required of them.

A style of this sort is fastened to the descending process of the malleus or incus by means of glue or pitch, in a line with the long axis of the process and extending downward for a distance of from half an inch to an inch, according to the size of the specimen and weight of the style, and inclined slightly toward the direction in which the carriage moves. The plate of glass, smoked evenly over an ordinary oil lamp, and attached to the carriage by metallic springs, is placed in position under the style, the point of which is brought lightly in contact with the surface of the plate by adjustment with the ratchet-wheel.

The membrana tympani being set in vibration, and the carriage, drawn by its weight, moving at a right angle to the excursion of the style, a wave line, corresponding to the character and pitch of the musical tone sounded into the ear, is traced upon the smoked glass.

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For preservation, the plate is then floated with varnish and allowed to dry and harden. In conducting the experiments with this apparatus, I am greatly indebted to the advice and co-operation of Prof. A. Graham Bell, of this city, who has also availed himself of this means in his investigations of the manner in which articulate sounds are produced.

The advantages in using the membrana tympani for the purpose of obtaining phonautograms are evident upon comparison with the various mechanical devices for accomplishing the same purpose, and a consideration of its structure gives sufficient evidence of its adaptability as an instrument for the purpose of recording the vibrations of a wide range of musical tones of varying character.

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